US010730539B2

(12) United States Patent
Meyer et al.

(10) **Patent No.: US 10,730,539 B2**
(45) **Date of Patent: *Aug. 4, 2020**

(54) **SYSTEM AND METHOD FOR CONTROLLING A VEHICLE SYSTEM**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **16/438,920**

(22) Filed: **Jun. 12, 2019**

(65) **Prior Publication Data**

US 2019/0291757 A1 Sep. 26, 2019

Related U.S. Application Data

(63) Continuation of application No. 15/864,518, filed on Jan. 8, 2018, now Pat. No. 10,363,949, which is a (Continued)

(51) **Int. Cl.**

B61L 27/00	(2006.01)
B61L 3/00	(2006.01)
B61L 25/02	(2006.01)

(52) **U.S. Cl.**
CPC .... ***B61L 27/0022*** (2013.01); ***B61L 3/006*** (2013.01); ***B61L 27/0016*** (2013.01); (Continued)

(58) **Field of Classification Search**
CPC B61L 27/0022
See application file for complete search history.

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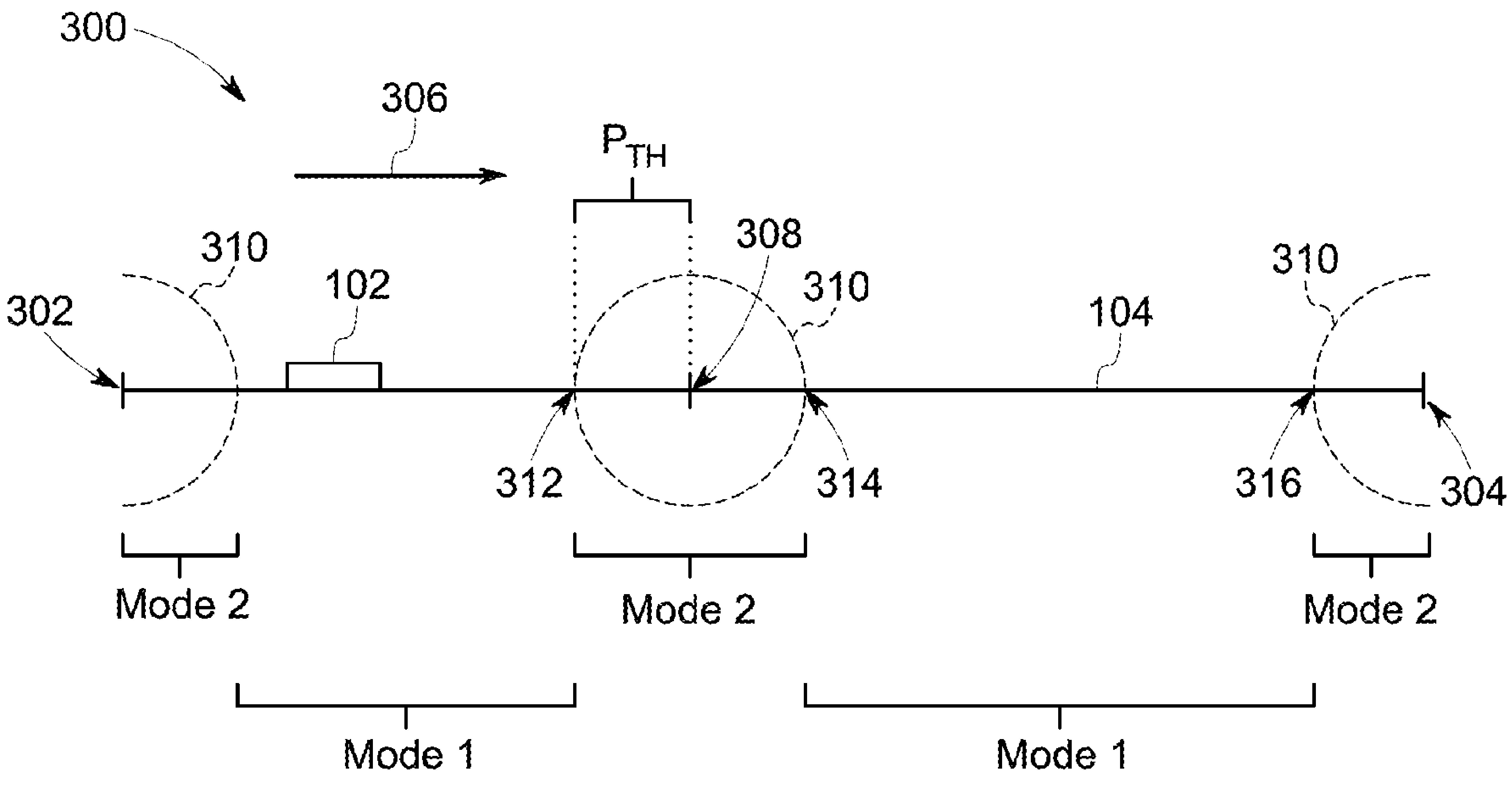
(57) **ABSTRACT**

A system (e.g., a control system) includes a sensor configured to monitor an operating condition of a vehicle system during movement of the vehicle system along a route. The system also includes a controller configured to designate one or more operational settings for the vehicle system as a function of time and/or distance along the route.

21 Claims, 3 Drawing Sheets



Related U.S. Application Data

continuation of application No. 15/058,772, filed on Mar. 2, 2016, now Pat. No. 9,862,397.

(60) Provisional application No. 62/128,290, filed on Mar. 4, 2015.

(52) **U.S. Cl.**
CPC ***B61L 27/0027*** (2013.01); *B61L 25/025* (2013.01); *B61L 2205/04* (2013.01)

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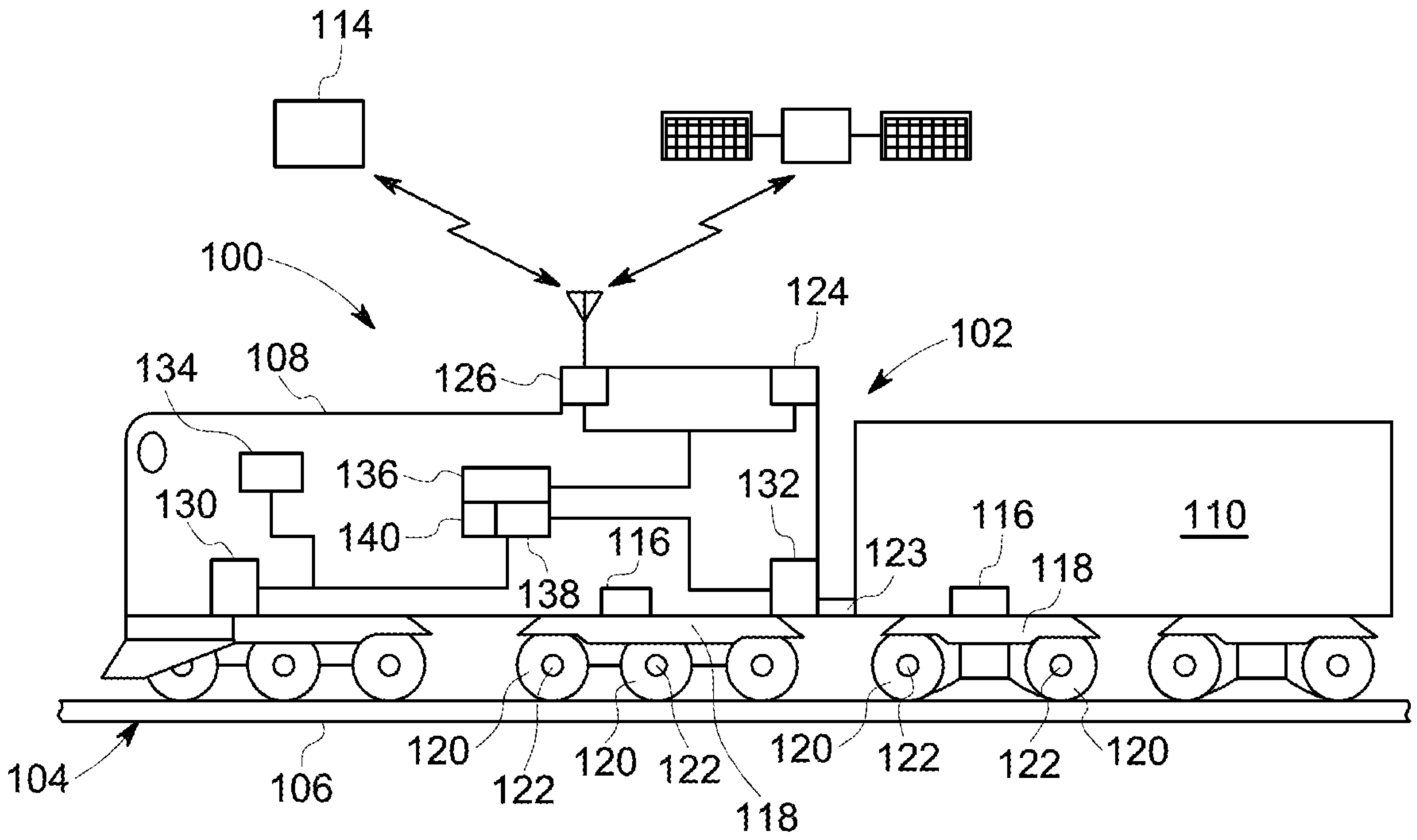
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100
102
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108
136
140
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132
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120
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120
122
118
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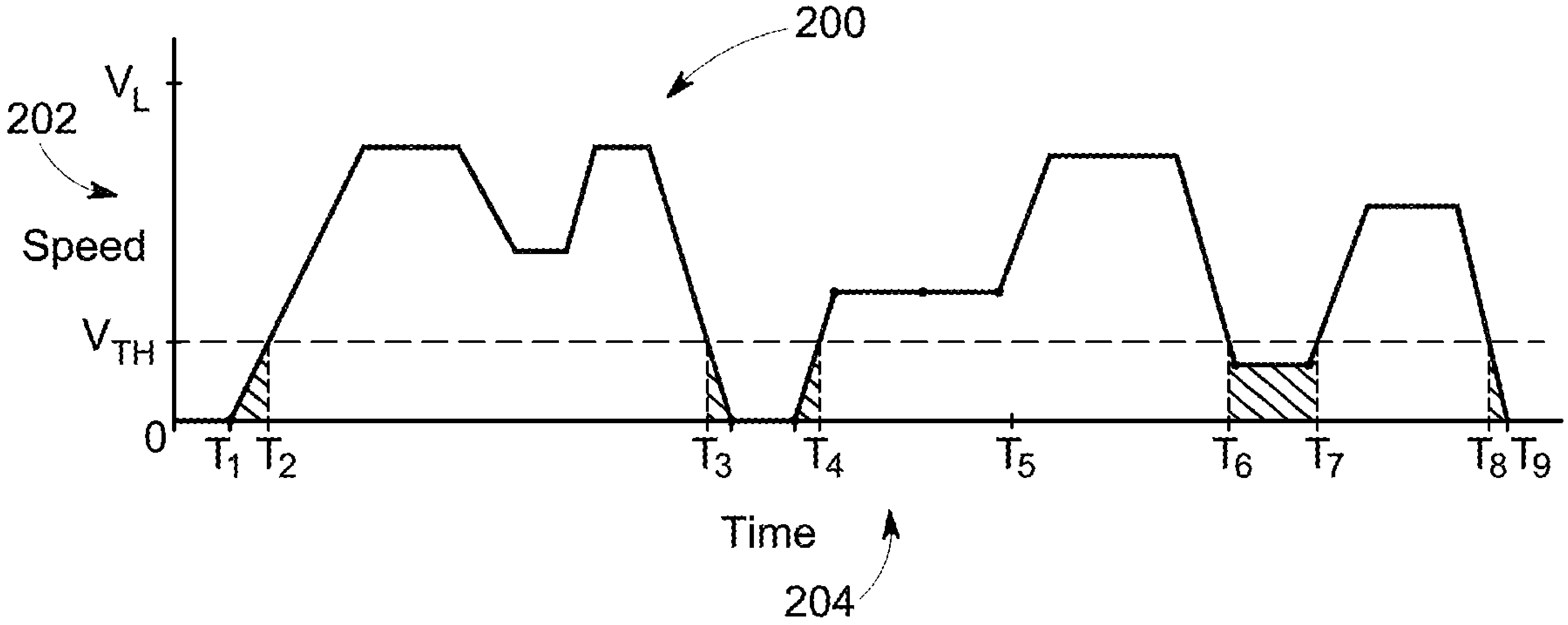
120

FIG. 1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V_L
202
Speed
V_{TH}
0
T_1
T_2
T_3
T_4
T_5
T_6
T_7
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T_9
Time
204

FIG. 2

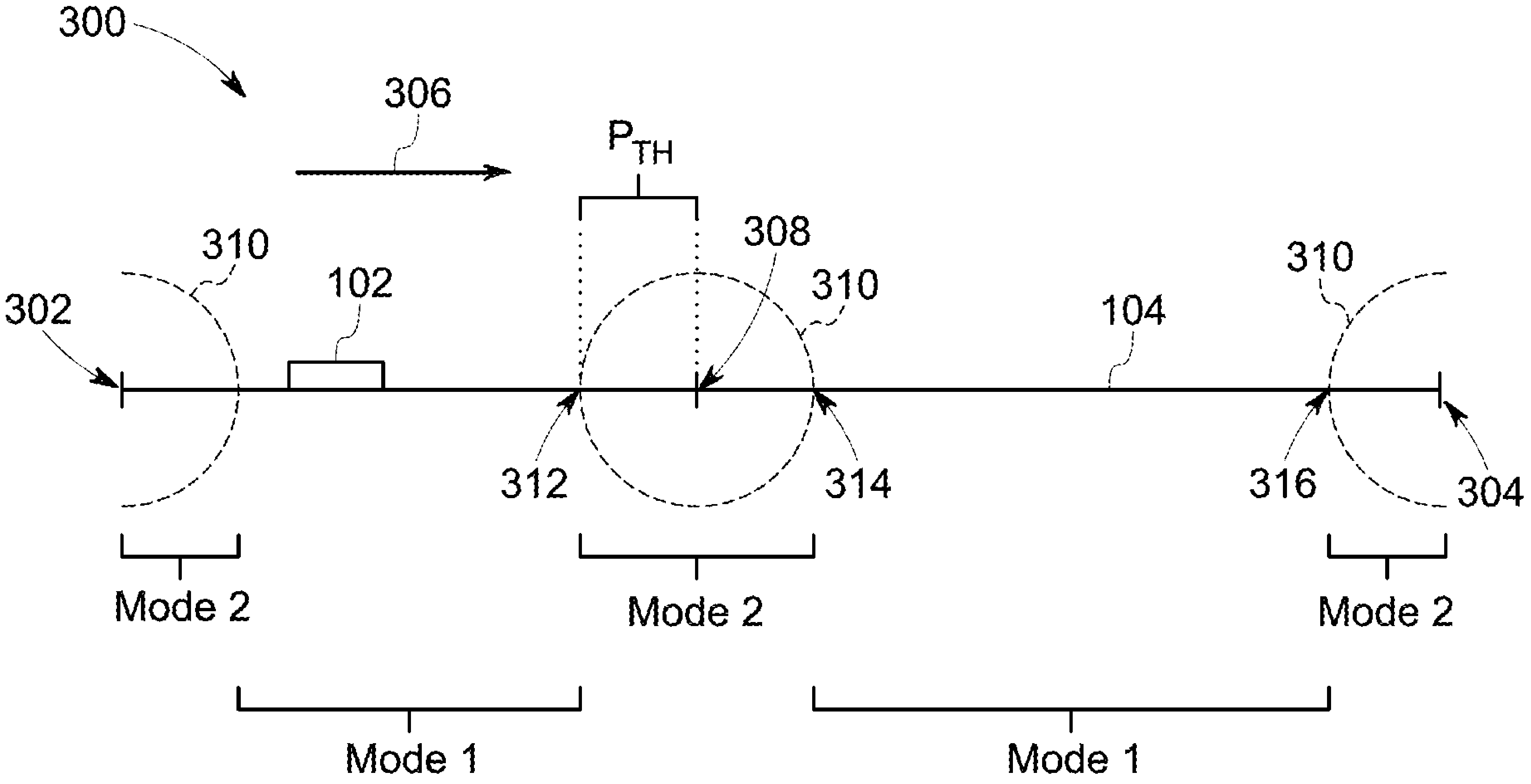
300
306
P_{TH}
310
308
310
310
302
102
104
312
314
316
304
Mode 2
Mode 2
Mode 2
Mode 1
Mode 1

FIG. 3

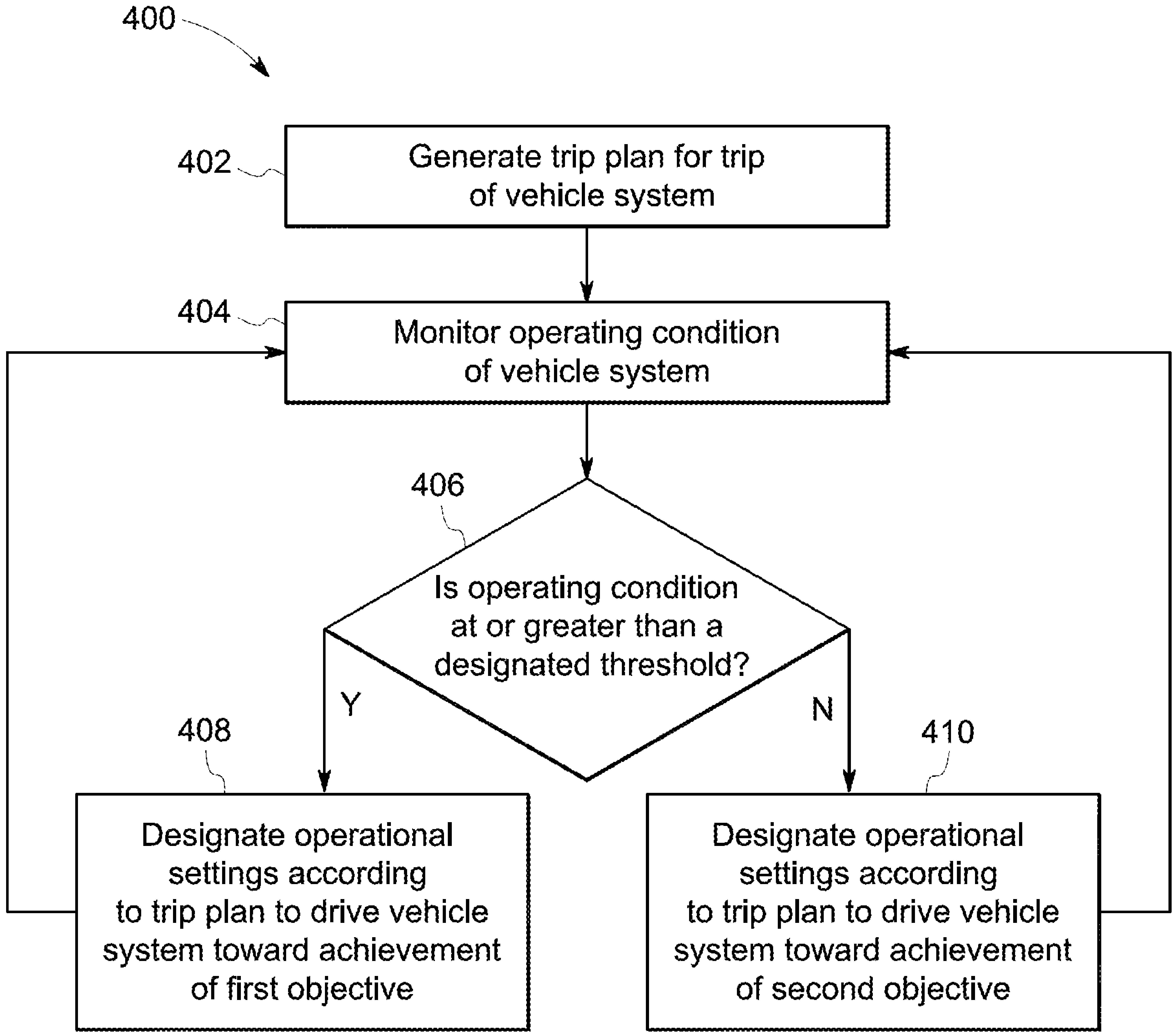
400
402
Generate trip plan for trip of vehicle system
404
Monitor operating condition of vehicle system
406
Is operating condition at or greater than a designated threshold?
Y
N
408
Designate operational settings according to trip plan to drive vehicle system toward achievement of first objective
410
Designate operational settings according to trip plan to drive vehicle system toward achievement of second objective

FIG. 4

SYSTEM AND METHOD FOR CONTROLLING A VEHICLE SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of, and claims priority to, U.S. patent application Ser. No. 15/864,518, filed 8 Jan. 2018, which is a continuation of, and claims priority to, U.S. patent application Ser. No. 15/058,772, filed 2 Mar. 2016 (now U.S. Pat. No. 9,862,397), which claims priority to U.S. Provisional Application No. 62/128,290, filed 4 Mar. 2015, all of which are incorporated herein by reference in their entireties.

FIELD

Embodiments of the subject matter described herein relate to a method and system for controlling a vehicle system traveling on a route.

BACKGROUND

Vehicle systems that travel on routes may travel on defined trips from starting or departure locations to destination or arrival locations. Each trip may extend along the route for long distances, and the trip may include one or more designated stops along the trip prior to reaching the arrival location, such as for a crew change, refueling, picking up or dropping off passengers and/or cargo, and the like. Some vehicle systems travel according to trip plans that provide instructions for the vehicle system to implement during movement of the vehicle system such that the vehicle system meets or achieves certain objectives during the trip. The objectives for the trip may include reaching the arrival location at or before a predefined arrival time, increasing fuel efficiency (relative to the fuel efficiency of the vehicle system traveling without following the trip plan), abiding by speed limits and emissions limits, and the like. The trip plans may be generated to achieve the specific objectives, so the instructions provided by the trip plans are based on those specific objectives.

Traveling according to trip plans can provide various benefits, such as fuel economy, as long as the objectives of the trip plan are relevant to the operations of the vehicle system. For example, the objective of increasing fuel efficiency is beneficial to the vehicle system as the vehicle system travels along an open section of the route at a planned running speed, but the same trip plan is not as beneficial if the section of the route has maintenance, congestion, or other constraints that limit the speed of the vehicle system to a speed below the planned running speed. In another example, the objective of increasing fuel economy is also not relevant near the designated stop locations (including the arrival location) along the route because the vehicle system has to travel at slow speeds to stop at the stop locations. Due to these issues, some operators of the vehicle system may choose to not follow the trip plan.

SUMMARY

In one embodiment, a system (e.g., a control system for controlling a vehicle system along a route) includes a sensor and a controller that includes one or more processors. The sensor is configured to monitor an operating condition of the vehicle system during movement of the vehicle system along the route for a trip. The controller is configured to designate one or more operational settings for the vehicle system as a function of one or more of time or distance along the route. The one or more operational settings are designated to drive the vehicle system toward achievement of one or more objectives for the trip. The controller is operable in at least two operating modes including a first operating mode and a second operating mode. The controller operates in the first operating mode responsive to the operating condition of the vehicle system being at least one of at or above a designated threshold. The controller in the first operating mode is configured to designate operational settings to drive the vehicle system during the trip toward achievement of a first objective during movement of the vehicle system along the route. The first objective includes one or more of a reduction in fuel consumption or a reduction in emissions generation by the vehicle system relative to the vehicle system traveling along the route for the trip according to operational settings that differ from the one or more operational settings designated by the controller. The controller operates in the second operating mode responsive to the operating condition of the vehicle system being below the designated threshold. The controller in the second operating mode is configured to designate operational settings to drive the vehicle system during the trip toward achievement of a different, second objective during movement of the vehicle system along the route.

In another embodiment, a method (e.g., for controlling a vehicle system along a route) includes generating a trip plan for a trip of the vehicle system along the route. The trip plan designates one or more operational settings for the vehicle system as a function of one or more of time or distance along the route. The one or more operational settings are designated to drive the vehicle system toward achievement of one or more objectives of the trip plan. The trip plan is generated to drive the vehicle system during the trip toward achievement of a first objective responsive to movement of the vehicle system along the route at a speed that is at least as fast as a designated threshold speed. The trip plan is generated to drive the vehicle system during the trip toward achievement of a different, second objective responsive to movement of the vehicle system along the route at a speed that is slower than the designated threshold speed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of one embodiment of a control system disposed onboard a vehicle system.

FIG. **2** is a schematic diagram showing a speed profile of the vehicle system traveling on a route during a trip according to one embodiment.

FIG. **3** is a schematic diagram showing a route profile of the vehicle system traveling on a segment of the route during a trip.

FIG. **4** is a flow chart of one embodiment of a method for controlling a vehicle system that travels on a route.

DETAILED DESCRIPTION

As used herein, an element or step recited in the singular and proceeded with the word "a" or "an" should be understood as not excluding plural of said elements or steps, unless such exclusion is explicitly stated. Furthermore, references to "one embodiment" of the present inventive subject matter are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features. Moreover, unless explicitly stated to the contrary, embodiments "comprising" or "having" an element or a plurality of elements having a particular property may include additional such elements not having that property.

As used herein, the terms "module," "system," "device," or "unit," may include a hardware and/or software system and circuitry that operate to perform one or more functions. For example, a module, unit, device, or system may include a computer processor, controller, or other logic-based device that performs operations based on instructions stored on a tangible and non-transitory computer readable storage medium, such as a computer memory. Alternatively, a module, unit, device, or system may include a hard-wired device that performs operations based on hard-wired logic and circuitry of the device. The modules, units, or systems shown in the attached figures may represent the hardware and circuitry that operates based on software or hardwired instructions, the software that directs hardware to perform the operations, or a combination thereof. The modules, systems, devices, or units can include or represent hardware circuits or circuitry that include and/or are connected with one or more processors, such as one or computer microprocessors.

Embodiments of the subject matter disclosed herein describe methods and systems used in conjunction with controlling a vehicle system that travels on a route. The embodiments provide methods and systems for controlling the vehicle system along the route in order to achieve different objectives based on different operating conditions of the vehicle system.

A more particular description of the inventive subject matter briefly described above will be rendered by reference to specific embodiments thereof that are illustrated in the appended drawings. The inventive subject matter will be described and explained with the understanding that these drawings depict only typical embodiments of the inventive subject matter and are not therefore to be considered to be limiting of its scope. Wherever possible, the same reference numerals used throughout the drawings refer to the same or like parts. To the extent that the figures illustrate diagrams of the functional blocks of various embodiments, the functional blocks are not necessarily indicative of the division between hardware and/or circuitry. Thus, for example, components represented by multiple functional blocks (for example, processors, controllers, or memories) may be implemented in a single piece of hardware (for example, a general-purpose signal processor, microcontroller, random access memory, hard disk, or the like). Similarly, any programs and devices may be standalone programs and devices, may be incorporated as subroutines in an operating system, may be functions in an installed software package, or the like. The various embodiments are not limited to the arrangements and instrumentality shown in the drawings.

FIG. **1** illustrates a schematic diagram of a control system **100** according to an embodiment. The control system **100** is disposed on a vehicle system **102**. The vehicle system **102** is configured to travel on a route **104**. The vehicle system **102** is configured to travel along the route **104** on a trip from a starting or departure location to a destination or arrival location. The vehicle system **102** includes a propulsion-generating vehicle **108** and a non-propulsion-generating vehicle **110** that are mechanically interconnected to one another in order to travel together along the route **104**. Alternatively, the vehicle system **102** may be formed from a single vehicle **108**.

The propulsion-generating vehicle **108** is configured to generate tractive efforts to propel (for example, pull or push) the non-propulsion-generating vehicle **110** along the route **104**. The propulsion-generating vehicle **108** includes a propulsion subsystem, including one or more traction motors, that generates tractive effort to propel the vehicle system **102**. The propulsion-generating vehicle **108** also includes a braking subsystem that generates braking effort for the vehicle system **102** to slow down or stop itself from moving. Optionally, the non-propulsion-generating vehicle **110** includes a braking subsystem but not a propulsion subsystem. The propulsion-generating vehicle **108** is referred to herein as a propulsion vehicle **108**, and the non-propulsion-generating vehicle **110** is referred to herein as a car **110**. Although one propulsion vehicle **108** and one car **110** are shown in FIG. **1**, the vehicle system **102** may include multiple propulsion vehicles **108** and/or multiple cars **110**. In an alternative embodiment, the vehicle system **102** only includes the propulsion vehicle **108** such that the propulsion vehicle **108** is not coupled to the car **110** or another kind of vehicle.

The control system **100** is used to control the movements of the vehicle system **102**. In the illustrated embodiment, the control system **100** is disposed entirely on the propulsion vehicle **108**. In other embodiments, however, one or more components of the control system **100** may be distributed among several vehicles, such as the vehicles **108**, **110** that make up the vehicle system **102**. For example, some components may be distributed among two or more propulsion vehicles **108** that are coupled together in a group or consist. In an alternative embodiment, at least some of the components of the control system **100** may be located remotely from the vehicle system **102**, such as at a dispatch location **114**. The remote components of the control system **100** may communicate with the vehicle system **102** (and with components of the control system **100** disposed thereon).

In the illustrated embodiment, the vehicle system **102** is a rail vehicle system, and the route **104** is a track formed by one or more rails **106**. The propulsion vehicle **108** may be a locomotive, and the car **110** may be a rail car that carries passengers and/or cargo. Alternatively, the propulsion vehicle **108** may be another type of rail vehicle other than a locomotive. In an alternative embodiment, the vehicle system **102** may be a non-rail vehicle system, such as an off-highway vehicle (OHV) system (e.g., a vehicle system that is not legally permitted and/or designed for travel on public roadways), an automobile, or the like. While some examples provided herein describe the route **104** as being a track, not all embodiments are limited to a rail vehicle traveling on a railroad track. One or more embodiments may be used in connection with non-rail vehicles and routes other than tracks, such as roads, waterways, or the like.

The vehicles **108**, **110** of the vehicle system **102** each include multiple wheels **120** that engage the route **104** and at least one axle **122** that couples left and right wheels **120** together (only the left wheels **120** are shown in FIG. **1**). Optionally, the wheels **120** and axles **122** are located on one or more trucks or bogies **118**. Optionally, the trucks **118** may be fixed-axle trucks, such that the wheels **120** are rotationally fixed to the axles **122**, so the left wheel **120** rotates the same speed, amount, and at the same times as the right wheel **120**. The propulsion vehicle **108** is mechanically coupled to the car **110** by a coupler **123**. The coupler **123** may have a draft gear configured to absorb compression and tension forces to reduce slack between the vehicles **108**, **110**. Although not shown in FIG. **1**, the propulsion vehicle **108** may have a coupler located at a front end **125** of the propulsion vehicle **108** and/or the car **110** may have a coupler located at a rear end **127** of the car **110** for mechanically coupling the respective vehicles **108**, **110** to additional vehicles in the vehicle system **102**.

As the vehicle system **102** travels along the route **104** during a trip, the control system **100** may be configured to measure, record, or otherwise receive and collect input information about the route **104**, the vehicle system **102**, and the movement of the vehicle system **102** on the route **104**. For example, the control system **100** may be configured to monitor a location of the vehicle system **102** along the route **104** and a speed at which the vehicle system **102** moves along the route **104**. In addition, the control system **100** may be configured to generate a trip plan and/or a control signal based on such information. The trip plan and/or control signal designates one or more operational settings for the vehicle system **102** to implement or execute during the trip as a function of time and/or location along the route **104**. The operational settings may include tractive and braking efforts for the vehicle system **102**. For example, the operational settings may include dictated speeds, throttle settings, brake settings, accelerations, or the like, of the vehicle system **102** as a function of time and/or distance along the route **104** traversed by the vehicle system **102**.

The trip plan is configured to achieve or increase specific goals or objectives during the trip of the vehicle system **102**, while meeting or abiding by designated constraints, restrictions, and limitations. Some possible objectives include increasing energy (e.g., fuel) efficiency, reducing emissions generation, reducing trip duration, increasing fine motor control, reducing wheel and route wear, and the like. The constraints or limitations include speed limits, schedules (such as arrival times at various designated locations), environmental regulations, standards, and the like. The operational settings of the trip plan are configured to increase the level of attainment of the specified objectives relative to the vehicle system **102** traveling along the route **104** for the trip according to operational settings that differ from the one or more operational settings of the trip plan (e.g., such as if the human operator of the vehicle system **102** determines the tractive and brake settings for the trip). One example of an objective of the trip plan is to increase fuel efficiency (e.g., by reducing fuel consumption) during the trip. By implementing the operational settings designated by the trip plan, the fuel consumed may be reduced relative to travel of the same vehicle system along the same segment of the route in the same time period but not according to the trip plan.

The trip plan may be established using an algorithm based on models for vehicle behavior for the vehicle system **102** along the route. The algorithm may include a series of non-linear differential equations derived from applicable physics equations with simplifying assumptions, such as described in connection with U.S. patent application Ser. No. 12/955,710, U.S. Pat. No. 8,655,516, entitled "Communication System for a Rail Vehicle Consist and Method for Communicating with a Rail Vehicle Consist," which was filed 29 Nov. 2010 (the "'516 Patent"), the entire disclosure of which is incorporated herein by reference.

Some known trip plans may not include multiple objectives that change based on conditions of the vehicle system. Since a trip plan with an objective of fuel efficiency may not be relevant as a vehicle system slows to a stop while approaching a designated stop location along the route, the trip plan may not be beneficial to an operator of the vehicle system while approaching and navigating the stop location at slow speeds. The trip plan may not be generated with an objective of fine motor control, so following instructions of the trip plan as the vehicle system approaches a stop location and exits the stop location may cause the vehicle system to stop and start abruptly, may cause the vehicle system to stop at an undesired or imprecise location relative to a desired stop location, and/or may cause wheel and/or track wear due to wheel slippage, for example.

In an embodiment, the control system **100** is configured to generate multiple trip plans for the vehicle system **102** to follow along the route **104** during the trip. The multiple trip plans may have different objectives from one another. The difference in objectives may be based on operating conditions of the vehicle system **102**. The operating conditions may be a speed of the vehicle system **102**, a location of the vehicle system **102** along the route, or the like. For example, the vehicle system **102** may move according to a first trip plan responsive to the vehicle system **102** is traveling at a speed that is at and/or above a designated threshold speed, and the vehicle system **102** may move according to a different, second trip plan responsive to the vehicle system **102** is traveling at a speed below the designated threshold speed. Both the first and second trip plans may be generated by the control system **100** prior to the vehicle system **102** embarking on the trip. Alternatively, only the first trip plan is generated prior to the trip, and the second trip plan is generated during the trip of the vehicle system **102** in response to the operating condition of the vehicle system **102** crossing the designated threshold. For example, the second trip plan may be a modified trip plan or a trip re-plan that modifies or updates the previously generated first trip plan to account for the changing objectives.

In an alternative embodiment, instead of generating multiple different trip plans, the control system **100** may be configured to generate a single trip plan that accounts for changing objectives of the vehicle system **102** along the route **104**. For example, the trip plan may constructively divide the trip into multiple segments based on time, location, or a projected speed of the vehicle system along the route. In some of the segments, the operational settings of the trip plan are designated to drive the vehicle system **102** toward achievement of at least a first objective. In at least one other segment, the operational settings of the trip plan are designated to drive the vehicle system **102** toward achievement of at least a different, second objective.

The control system **100** may be configured to control the vehicle system **102** along the trip based on the trip plan, such that the vehicle system **102** travels according to the trip plan. In a closed loop mode or configuration, the control system **100** may autonomously control or implement propulsion and braking subsystems of the vehicle system **102** consistent with the trip plan, without requiring the input of a human operator. In an open loop coaching mode, the operator is involved in the control of the vehicle system **102** according to the trip plan. For example, the control system **100** may present or display the operational settings of the trip plan to the operator as directions on how to control the vehicle system **102** to follow the trip plan. The operator may then control the vehicle system **102** in response to the directions. As an example, the control system **100** may be or include a Trip Optimizer™ system from General Electric Company, or another energy management system. For additional discussion regarding a trip plan, see the '516 Patent.

The control system **100** includes multiple sensors configured to monitor operating conditions of the vehicle system **102** during movement of the vehicle system **102** along the route **104** during for a trip. The multiple sensors may monitor data that is communicated to a controller **136** of the control system **100** for processing and analysis of the data. For example, the controller **136** may generate a trip plan based on the data received from one or more of the sensors. One such type of sensor is a speed sensor **116** disposed on the vehicle system **102**. In the illustrated embodiment, multiple speed sensors **116** are located on or near the trucks **118**. The speed sensor **116** is configured to monitor a speed of the vehicle system **102** as the vehicle system **102** traverses the route **104**. The speed sensor **116** may be a speedometer, a vehicle speed sensor (VSS), or the like. The speed sensor **116** may provide a speed parameter to the controller **136**, where the speed parameter is associated with a current speed of the vehicle system **102**. The speed parameter may be communicated to the controller **136** periodically, such as once every second or every two seconds, or upon receiving a request for the speed parameter.

Another sensor of the control system **100** is a locator device **124**. The locator device **124** is configured to determine a location of the vehicle system **102** on the route **104**. The locator device **124** may be a global positioning system (GPS) receiver. Alternatively, the locator device **124** may include a system of sensors including wayside devices (e.g., including radio frequency automatic equipment identification (RF AEI) tags), video or image acquisition devices, or the like. The locator device **124** may provide a location parameter to the controller **136**, where the location parameter is associated with a current location of the vehicle system **102**. The location parameter may be communicated to the controller **136** periodically or upon receiving a request for the speed parameter. The controller **136** may use the location of the vehicle system **102** to determine the proximity of the vehicle system **102** to one or more designated locations of the trip. For example, the designated locations may include an arrival location at the end of the trip, a passing loop location along the route **104** where another vehicle system on the route **104** is scheduled to pass the vehicle system **102**, a break location for re-fueling, crew change, passenger change, or cargo change, and the like.

The control system **100** also includes additional sensors **132** that measure other operating conditions or parameters of the vehicle system **102** during the trip (e.g., besides speed and location). The additional sensors **132** may include throttle and brake position sensors that monitor the positions of manually operated throttle and brake controls, respectively, and communicate control signals to the respective propulsion and braking subsystems. The sensors **132** may also include sensors that monitor power output by the motors of the propulsion subsystem and the brakes of the braking subsystem to determine the current tractive and braking efforts of the vehicle system **102**. Furthermore, the control system **100** may include string potentiometers (referred to herein as string pots) between at least some of the vehicles **108**, **110** of the vehicle system **102**, such as on or proximate to the couplers **123**. The string pots may monitor a relative distance and/or a longitudinal force between two vehicles. For example, the couplers **123** between two vehicles may allow for some free movement or slack of one of the vehicles before the force is exerted on the other vehicle. As the one vehicle moves, longitudinal compression and tension forces shorten and lengthen the distance between the two vehicles like a spring. The string pots are used to monitor the slack between the vehicles of the vehicle system **102**. The above represents a short list of possible sensors that may be on the vehicle system **102** and used by the control system **100**, and it is recognized that the vehicle system **102** and/or the control system **100** may include more sensors, fewer sensors, and/or different sensors.

The control system **100** may further include a wireless communication system **126** that allows wireless communications between vehicles **108**, **110** in the vehicle system **102** and/or with remote locations, such as the remote (dispatch) location **114**. The communication system **126** may include a receiver and a transmitter, or a transceiver that performs both receiving and transmitting functions. The communication system **126** may include an antenna and associated circuitry.

In an embodiment, the control system **100** includes a vehicle characterization element **134** that provides information about the vehicle system **102**. The vehicle characterization element **134** provides information about the make-up of the vehicle system **102**, such as the type of cars **110** (for example, the manufacturer, the product number, the materials, etc.), the number of cars **110**, the weight of cars **110**, whether the cars **110** are consistent (meaning relatively identical in weight and distribution throughout the length of the vehicle system **102**) or inconsistent, the type and weight of cargo, the total weight of the vehicle system **102**, the number of propulsion vehicles **108**, the position and arrangement of propulsion vehicles **108** relative to the cars **110**, the type of propulsion vehicles **108** (including the manufacturer, the product number, power output capabilities, available notch settings, fuel usage rates, etc.), and the like. The vehicle characterization element **134** may be a database stored in an electronic storage device, or memory. The information in the vehicle characterization element **134** may be input using an input/output (I/O) device (referred to as a user interface device) by an operator, may be automatically uploaded, or may be received remotely via the communication system **126**. The source for at least some of the information in the vehicle characterization element **134** may be a vehicle manifest, a log, or the like.

The control system **100** further includes a trip characterization element **130**. The trip characterization element **130** is configured to provide information about the trip of the vehicle system **102** along the route **104**. The trip information may include route characteristics, designated locations, designated stopping locations, schedule times, meet-up events, directions along the route **104**, and the like. For example, the designated route characteristics may include grade, elevation slow warnings, environmental conditions (e.g., rain and snow), and curvature information. The designated locations may include the locations of wayside devices, passing loops, re-fueling stations, passenger, crew, and/or cargo changing stations, and the starting and destination locations for the trip. At least some of the designated locations may be designated stopping locations where the vehicle system **102** is scheduled to come to a complete stop for a period of time. For example, a passenger changing station may be a designated stopping location, while a wayside device may be a designated location that is not a stopping location. The wayside device may be used to check on the on-time status of the vehicle system **102** by comparing the actual time at which the vehicle system **102** passes the designated wayside device along the route **104** to a projected time for the vehicle system **102** to pass the wayside device according to the trip plan. The trip information concerning schedule times may include departure times and arrival times for the overall trip, times for reaching designated locations, and/or arrival times, break times (e.g., the time that the vehicle system **102** is stopped), and departure times at various designated stopping locations during the trip. The meet-up events include locations of passing loops and timing information for passing, or getting passed by, another vehicle system on the same route. The directions along the route **104** are directions used to traverse the route **104** to reach the destination or arrival location. The directions may be updated to provide a path around a congested area or a construction or maintenance area of the route. The trip characterization element **130** may be a database stored in an electronic storage device, or memory. The information in the trip characterization element **130** may be input via the user interface device by an operator, may be automatically uploaded, or may be received remotely via the communication system **126**. The source for at least some of the information in the trip characterization element **130** may be a trip manifest, a log, or the like.

The control system **100** has a controller **136** or control unit that is a hardware and/or software system which operates to perform one or more functions for the vehicle system **102**. The controller **136** receives information from components of the control system **100**, analyzes the received information, and generates operational settings for the vehicle system **102** to control the movements of the vehicle system **102**. The operational settings may be contained in a trip plan. The controller **136** has access to, or receives information from, the speed sensor **116**, the locator device **124**, the vehicle characterization element **134**, the trip characterization element **130**, and at least some of the other sensors **132** on the vehicle system **102**. The controller **136** may be a device that includes a housing and one or more processors **138** therein (e.g., within a housing). Each processor **138** may include a microprocessor or equivalent control circuitry. At least one algorithm operates within the one or more processors **138**. For example, the one or more processors **138** may operate according to one or more algorithms to generate a trip plan.

The controller **136** optionally may also include a controller memory **140**, which is an electronic, computer-readable storage device or medium. The controller memory **140** may be housed in the housing of the controller **136**, or alternatively may be on a separate device that is communicatively coupled to the controller **136** and the one or more processors **138** therein. By "communicatively coupled," it is meant that two devices, systems, subsystems, assemblies, modules, components, and the like, are joined by one or more wired or wireless communication links, such as by one or more conductive (e.g., copper) wires, cables, or buses; wireless networks; fiber optic cables, and the like. The controller memory **140** can include a tangible, non-transitory computer-readable storage medium that stores data on a temporary or permanent basis for use by the one or more processors **138**. The memory **140** may include one or more volatile and/or non-volatile memory devices, such as random access memory (RAM), static random access memory (SRAM), dynamic RAM (DRAM), another type of RAM, read only memory (ROM), flash memory, magnetic storage devices (e.g., hard discs, floppy discs, or magnetic tapes), optical discs, and the like.

In an embodiment, using the information received from the speed sensor **116**, the locator device **124**, the vehicle characterization element **134**, and trip characterization element **130**, the controller **136** is configured to designate one or more operational settings for the vehicle system **102** as a function of time and/or distance along the route **104** during a trip. The one or more operational settings are designated to drive or control the movements of the vehicle system **102** during the trip toward achievement of one or more objectives for the trip. In an embodiment, the controller **136** is operable in at least two operating modes in order to accommodate different objectives for different portions of the trip. For example, the controller **136** in a first operating mode is configured to designate operational settings to drive the vehicle system **102** toward achievement of at least a first objective. The controller **136** in a second operating mode, on the other hand, is configured to designate operational settings to drive the vehicle system **102** toward achievement of at least a different, second objective. The controller **136** in an embodiment is configured to switch between the first and second operating mode when an operating condition of the vehicle system **102** crosses a designated threshold, as described further below with reference to FIGS. **2** and **3**.

The operational settings may be one or more of speeds, throttle settings, brake settings, or accelerations for the vehicle system **102** to implement during the trip. Optionally, the controller **136** may be configured to communicate at least some of the operational settings designated by the controller **136** in a control signal. The control signal may be directed to the propulsion subsystem, the braking subsystem, or a user interface device of the vehicle system **102**. For example, the control signal may be directed to the propulsion subsystem and may include notch throttle settings of a traction motor for the propulsion subsystem to implement autonomously upon receipt of the control signal. In another example, the control signal may be directed to a user interface device that displays and/or otherwise presents information to a human operator of the vehicle system **102**. The control signal to the user interface device may include throttle settings for a throttle that controls the propulsion subsystem, for example. The control signal may also include data for displaying the throttle settings visually on a display of the user interface device and/or for alerting the operator audibly using a speaker of the user interface device. The throttle settings optionally may be presented as a suggestion to the operator, for the operator to decide whether to implement the suggested throttle settings.

FIG. **2** is a schematic diagram showing a speed profile **200** of the vehicle system **102** (shown in FIG. **1**) traveling on the route **104** (FIG. **1**) during a trip according to an embodiment. The speed profile **200** plots a speed **202** or velocity of the vehicle system **102** over time **204** during the trip. The speed profile **200** of the vehicle system **102** may travel according to a trip plan (e.g., operational settings designated by the trip plan) generated by the controller **136** (FIG. **1**) of the control system **100** (FIG. **1**).

As stated above, the controller **136** may switch between a first and second operating mode when an operating condition of the vehicle system **102** crosses a designated threshold. In the illustrated embodiment, the operating condition that is used to determine the operating mode of the controller **136** is a speed of the vehicle system **102** along the route. The designated threshold is a threshold speed (shown in FIG. **2** as V_{TH}). In an embodiment, the controller **136** may operate in a first operating mode based on or responsive to the speed of the vehicle system **102** being at least at or above the threshold speed, and the controller **136** may operate in the second operating mode based on or responsive to the speed of the vehicle system **102** falling below the threshold speed.

During the trip, as shown in the speed profile **200**, the speed of the vehicle system **102** may cross the threshold speed multiple times. For example, the vehicle system **102** travels faster than the threshold speed during a majority of the trip. The controller **136** thus operates in the first operating mode for the majority of the duration of the trip. Yet, when the vehicle system **102** starts on the trip or otherwise accelerates from a stopped position, the speed of the vehicle system **102** is at least temporarily below the threshold speed. Likewise, the speed of the vehicle system **102** is below the threshold speed when the vehicle system **102** slows to a stop at the end of the trip or at another designated stopping location along the route **104**. Thus, the controller **136** operates in the second operating mode at least at the times when the vehicle system **102** is slowing to a stop or accelerating from a stop.

In an embodiment, the objectives for the movement of the vehicle system **102** change responsive to a change in the operating mode of the controller **136**. In the first operating mode, when the vehicle system **102** travels faster than the threshold speed, the controller **136** designates operational settings to drive the vehicle system **102** to achieve a first objective. The first objective may be one or more of a reduction in fuel consumption by the vehicle system **102**, a reduction in emissions generation by the vehicle system **102**, improved handling of the vehicle system **102**, or a reduction in travel time during the trip. The first objective may include multiple objectives, such as more than one of the objectives listed above. The reduction in fuel consumption, emissions generation, and/or travel time, and the improvement in handling achieved by implementing the designated operational settings is relative to the vehicle system **102** traveling along the route for the trip according to operational settings that differ from the operational settings designated by the controller **136**. For example, the operational settings designated by the controller **136** may produce a driving strategy with less drag loss and/or less braking loss compared to a driving strategy determined by a human operator.

The controller **136** may be configured to designate the operational settings to drive the vehicle system **102** toward achievement of the first objective while satisfying one or more constraints. For example, the constraints may include speed limits along the route **104**, vehicle capability constraints, trip schedule times, emissions limits, and the like. Thus, as the vehicle system **102** implements the designated operational settings, the vehicle system **102** does not exceed the specified constraints for the relevant segment of the route **104**. For example, the speed limits may be permanent or temporary speed limits set by the railroad or highway authority. The temporary speed limits may be due to construction, maintenance, or congestion on the route **104**. The vehicle capability constraints may include power output capabilities of the motors of the propulsion vehicle **108** (FIG. **1**), notch settings of the propulsion vehicle **108**, and/or available fuel supply on the vehicle system. Thus, the controller **136** is configured to not designate operational settings that require the propulsion vehicle **108** to provide more power than the propulsion vehicle **108** can reasonably supply. The trip schedule times include designated times for the trip, such as the projected arrival time at the destination location, scheduled meet-up times, and times that the vehicle system **102** should reach designated route markers, such as wayside devices and/or stopping locations. The emissions limits may include limitations on fuel emissions, noise emissions, and the like, as designated by the Environmental Protection Agency (EPA), railroad companies, municipalities, and other regulatory authorities. Some of the constraints may be determined using information from the vehicle characterization element **134** (such as vehicle capability limitations) and information from the trip characterization element **130** (such as speed limits and schedule times). Other constraints may be determined using information received from a remote source via the wireless communication system **126**.

In an embodiment, the first objective may be to reduce fuel consumption by the vehicle system **102** along the length of the route **104** subject to the above constraints, such as emissions limits and speed limits. In another embodiment, the first objective may be to reduce emissions generated by the vehicle system **102**, subject to constraints such as fuel use and/or scheduled arrival time. In yet another example, the first objective may be to reduce the travel time without constraints on total emissions generated and/or fuel consumed where such relaxation of constraints would be permitted or required for the trip. The reduction in travel time may refer to a reduction in total travel time during the trip between the departure location and the destination location, and/or may refer to travel time along segments of the trip. Optionally, the first objective may include more than a single objective, such that the first objective includes both reducing fuel consumption and emissions generation of the vehicle system **102** along the route **104** subject to constraints such as speed limits, vehicle capability constraints, and trip schedule times.

The handling of the vehicle system **102** may involve controlling the forces exerted within the couplers between individual vehicles of the vehicle system **102**. For example, prospective forces that are expected or calculated as being exerted on and/or experienced by couplers in the vehicle system may be reduced by limiting the allowable speeds of the vehicle system. The allowable speeds may be limited to speeds that are slower than speed dictated by a trip plan of the vehicle system **102**, speed limits of the route, or the like. The handling of the vehicle system **102** can be improved in that the coupler forces between vehicles are reduced relative to vehicle systems that travel along the same routes without limiting the allowable speeds of the vehicle systems. The allowable speeds of the vehicle system **102** may be restricted in those locations or segments of the route where the larger prospective forces on the couplers are expected to occur, while the allowable speeds of the vehicle system **102** may not be restricted in other locations. As a result, the vehicle system **102** may be able to travel at or near the designated speeds of a trip plan, the speed limits of the route, or the like, for most of a trip such that the vehicle system **102** can remain on schedule or complete the trip in a time period closer to the time period contemplated by the trip plan and/or speed limits of the route. The vehicle handling may also include controlling the spacing between individual vehicles in the vehicle system. For example, the vehicle system **102** may be controlled to manage the tension and compression in the couplers to maintain the forces within acceptable designated limits, which also affects the spacing between vehicles.

Once the first objective is identified, the controller **136** may generate the operational settings for the vehicle system **102** for a segment of the route **104** subject to applicable constraints. The operational settings may be contained in a trip plan that is generated by the controller **136**. As described above, the controller **136** receives relevant information about the trip, the vehicle system **102**, and the route **104**. The controller **136** may generate a trip plan using an algorithm based on models for vehicle behavior for the vehicle system **102** along the route **104**. The algorithm may include a series of non-linear differential equations derived from applicable physics equations with simplifying assumptions, such as described in connection with the '516 Patent. For example, for a first objective of reducing fuel consumption, the controller **136** may consult a plotted fuel-use over travel time curve that has been created using data from previous trips of different vehicle systems over the route at different speeds. The generated trip plan designates operational settings for the vehicle system **102** as a function of time and/or distance along the route **104**. The operational settings are designated to drive the vehicle system **102** toward achievement of the first objective. Thus, responsive to the vehicle system **102** is traveling at or above the threshold speed, the controller **136** is in the first operating mode. In the first operating mode, the controller **136** designates operational settings, according to a trip plan, in order to drive the vehicle system **102** toward achievement of the first objective, which includes reducing fuel consumption, reducing emissions generation, improving vehicle handling, and/or reducing total travel time.

In an embodiment, the threshold speed is a speed that is selected prior to the trip of the vehicle system **102**. For example, the threshold speed may be a speed between 3 miles per hour (mph) (4.5 kph) and 20 mph (33 kph), or, more specifically, between 5 mph (8 kph) and 15 mph (25 kph). The threshold speed could be 5 mph, 10 mph, or 15 mph in various embodiments. The threshold speed may depend on the type of vehicle system **102**. For example, the threshold speed for a vehicle system **102** that is a rail vehicle may be lower than a threshold speed for a vehicle system **102** that is an off-highway vehicle and may be higher than a threshold speed for a vehicle system **102** that is a water vessel.

In an embodiment, based on or responsive to the operating condition of the vehicle system **102** falling below the designated threshold, the operating mode of the controller **136** changes as well as the objectives for the movement of the vehicle system **102**. For example, when the speed of the vehicle system **102** is below the threshold speed, the controller **136** operates in the second operating mode. In the second operating mode, the controller **136** designates operational settings to drive the vehicle system **102** to achieve a second objective that differs from the first objective. In one embodiment, the operating mode of the controller **136** and the objective of the movement of the vehicle system **102** change automatically upon the operating condition of the vehicle system **102** crossing the threshold. For example, even if the speed of the vehicle system **102** coincidentally or unintentionally falls below the designated speed threshold, the switch in operating mode of the controller **136** and objective of the movement of the vehicle system **102** is triggered. Alternatively, the switch in the operating mode and the movement objectives may occur based on the operating condition crossing the threshold, but not automatically. For example, upon detecting that the operating condition has crossed the designated threshold, the controller **136** may provide a notification to an on-board human operator, requesting or suggesting the change in operating conditions of the controller **136** and the change in movement objectives of the vehicle system **102**. Thus, the human operator may have the option and final authority on whether to proceed with the change or not.

The operating mode of the controller **136** changes based on the operating condition of the vehicle system **102** to switch objectives for the movement of the vehicle system **102** because the relevancy or priority of objectives may change with changing circumstances or conditions of the vehicle system **102** along the route **104**. For example, when the vehicle system **102** is traveling at speeds over the threshold speed, the relevant objectives may be reducing fuel consumption, reducing emissions generation, and/or reducing total travel time for the trip. These objectives are relevant at speeds over the threshold speed as the vehicle system **102** may traverse a majority of the distance of the route **104** at such speeds. On the other hand, the vehicle system **102** may move at speeds below the threshold speed when the vehicle system **102** is slowing to a stop or accelerating from a stop, for example. At these conditions or circumstances, the fuel efficiency of the vehicle system **102** may not be as high of a priority as other objectives, such fine motor control. Thus, fine motor control of the vehicle system **102** may be more relevant than fuel efficiency at speeds of the vehicle system **102** below the threshold speed. For this reason, the controller **136** changes operating modes from the first operating mode to the second operating mode when the speed of the vehicle system **102** falls below the threshold speed in order to designate operational settings that drive the vehicle system **102** toward achievement of a different, second objective that is more relevant to the vehicle system **102** at that speed than the first objective.

In an embodiment, the second objective relates to fine control over the vehicle system **102**, which is useful for controlling the vehicle system **102** at slow speeds. Fine motor control may be beneficial as the vehicle system **102** approaches, reaches, and departs designated stopping locations. For example, the second objective may include moving the vehicle system **102** to one or more locations that are within a designated threshold distance of one or more designated locations of the trip.

The designated locations may include stopping locations (such as the destination location or a break location) designated in the trip schedule. For example, as the vehicle system **102** approaches a station in order to change personnel and/or passengers, the station may have designated markers that indicate where the vehicle system **102** is to come to a stop. The station may be relatively long, such that some vehicle systems are designated to stop at different locations than other vehicle systems in order to pick up or drop off the appropriate passengers and/or personnel. The markers may indicate where the propulsion vehicle **108** of the vehicle system **102** is to stop. Since it is recognized that vehicle systems may not be able to stop exactly at a designated marker at a stopping location, the station and/or the transit authority may request that the vehicle system **102** stop within a designated threshold distance, before or after, the marker. In an embodiment, the second objective may be to stop the vehicle system **102** at a location that is within the designated threshold distance of the designated stopping location of the trip. To accomplish the second objective, the controller **136** may designate operational settings for the vehicle system **102** to implement in order to practice fine motor control over the vehicle system **102**. For example, the operational settings may include slight adjustments to tractive efforts of the traction motors of the propulsion subsystem and slight adjustments to braking efforts of the braking subsystem to accomplish stopping the vehicle system **102** within the designated threshold distance from a designated stopping location.

The operational settings designated by the controller **136** (e.g., according to a trip plan) may allow the vehicle system **102** to stop within a closer proximity to the designated stopping location than if the vehicle system **102** was being controlled solely by a human operator. In addition, the operational settings designated by the controller **136** to drive the vehicle system **102** toward achievement of the second objective may allow the vehicle system **102** to stop within a closer proximity to the designated stopping location than if the operational settings were designated to drive the vehicle system **102** toward achievement of the first objective. For example, the fine motor control required in order to stop the vehicle system **102** at such a close proximity to the designated stopping location may not have been attainable if the vehicle system **102** is driven to achieve a different objective, such as fuel economy. The fine motor controls to drive the vehicle system **102** toward achievement of the second objective may consume more fuel, generate more emissions, and/or take a longer amount of time to stop the vehicle system **102** than if the vehicle system **102** were being driven toward achievement of the first objective. However, as the vehicle system **102** is approaching a stop, such as a station, the fuel consumption, emissions generation, and/or time of travel may not be as high of a priority as making sure that the vehicle system **102** stops accurately within a threshold distance of a designated stopping location.

In another example, the second objective includes stopping the vehicle system **102** such that multiple vehicles of the vehicle system **102** are bunched together with one or more couplers disposed between the vehicles in a slack state (for example, a state of having slack) once the vehicle system **102** is stopped. As shown in FIG. **1**, the vehicles **108**, **110** of the vehicle system **102** are coupled together by coupler devices **123**. The couplers **123** are configured to absorb longitudinal forces between the vehicles of the vehicle system **102** (such as the vehicles **108**, **110**). As the vehicle system **102** moves, longitudinal compression and tension forces shorten and lengthen the distance between the two vehicles. The couplers **123** may be configured to allow for some free movement or slack of a first vehicle before the force is exerted on a second vehicle that is coupled to the first vehicle. When the coupler **123** between two vehicles is not under tension (or the tension in the coupler has a magnitude below a designated threshold), the coupler **123** may be referred to as being in a slack state or slack condition. The slack state is in comparison to a stretch state of the coupler when the tension in the coupler has a magnitude greater than a designated threshold. It may be desirable in some situations for the couplers of a vehicle system to be in the slack state when the vehicle system is stopped because, when the vehicle system starts moving again, the propulsion vehicles do not have to pull the entire load of the vehicle system from the stationary position at the same time. Instead, due to the accumulation of slack between the vehicles (also referred to as bunching), each propulsion vehicle originally pulls a first car until the slack between the first car and the second car is reduced, at which time the propulsion vehicle pulls the first car and the second car. Thus, due to bunching, the propulsion vehicle may be able to build up momentum over time without having to pull the entire load of the vehicle system at once from a stopped position.

As stated above, the second objective may be to stop the vehicle system **102** such that multiple vehicles **108**, **110** of the vehicle system **102** are bunched together when the vehicle system **102** is stopped, which enhances the ability for the vehicle system **102** to start moving again after the stop. The controller **136** may designate operational settings (e.g., according to a trip plan) that provide for fine control over the tractive efforts and braking efforts of the vehicle system **102** as the vehicle system **102** slows to a stop for the couplers **123** to attain the slack state. For example, the operational settings may control the braking subsystem to slow the vehicles consecutively such that each vehicle comes to a stop a fraction after the preceding vehicle in the vehicle system **102**, which provides slack in the corresponding coupler **123**. The controller **136** may designate the operational settings based on slack information received from string pots located between the vehicles. Stopping the vehicle system **102** in this way to achieve bunching may require more fuel consumption, emissions generation, and/or time than stopping the vehicle system **102** using operational settings designated to achieve the first objective. But the operational settings designated to drive the vehicle system **102** to achieve the first objective would likely not be able to be used to achieve such bunching. Furthermore, due to benefit that bunching may provide the vehicle system **102** as the vehicle system **102** starts moving again, stopping the vehicle system **102** to achieve bunching may be more relevant or a higher priority than stopping the vehicle system **102** to achieve fuel efficiency or to save time, for example.

In a further example, the second objective includes moving the vehicle system **102** on the route **104** such that one or more wheels **120** of the vehicle system **102** retain adhesion with the route **104** to reduce wheel slip. Wheel slip is a phenomenon that typically occurs as the vehicle system **102** is braking or accelerating. A wheel **120** may “slip” on the route **104** when the rotational force in a forward direction (e.g., when accelerating) or in a reverse direction (e.g., when braking) exceeds the frictional force between the wheel **120** and the route **104**, so the wheel **120** rotates relative to the route **104**. Wheel slip results in skidding of the wheel **120** along the route **104**, which causes wheel and route wear, and could cause more damage (e.g., such as a derailment) if not timely repaired. Wheel slip wears the wheels **120** and the route **104** to the extent that the wheels **120** and applicable segments of the route **104** must be replaced more often than would otherwise be required, so avoiding wheel slip is desirable from both an economic and a safety perspective.

As stated above, the second objective may be to move the vehicle system **102** on the route **104** such that one or more wheels **120** of the vehicle system **102** retain adhesion with the route **104** to reduce wheel slip. The controller **136** may designate operational settings (e.g., according to a trip plan) that provide for fine control over the tractive efforts and braking efforts of the vehicle system **102** as the vehicle system **102** brakes and/or accelerates at speeds below the threshold speed to reduce the risk of wheel slip. For example, the operational settings may control the braking subsystem to slow the vehicles gradually over a period of time in order to reduce the rotational force on each wheel **120**. For example, the period of time that the brakes are applied in accordance with the operational settings to achieve the second objective may be longer than the period of time that the brakes may be applied in accordance with operational settings designated to achieve the first objective (such as fuel efficiency or reduced travel time). Thus, the additional time and/or distance for braking allows for a reduction in the rotational force applied on the wheels **120**, such that wheel slip is less likely than if the vehicle system **102** is being stopped according to the operational settings to achieve the first objective. For example, if the first objective is to reduce travel time, the operational settings may control the vehicle system **102** to apply the brakes at a later time and/or location and at a greater setting to reduce the time spent slowing the vehicle system **102**. But the greater brake application may cause wheel slip which may result in costly repairs to the vehicle system **102** and/or the route **104**. Although the example above concerns the application of the brakes by the braking subsystem, the operational settings may also control the propulsion subsystem to accelerate the vehicle system **102** gradually over a period of time in order to reduce the forward rotational force on each wheel **120**. At speeds below the designated threshold speed, the potential costs of wheel slippage (e.g., replacing segments of the route **104** and/or wheels and other equipment on the vehicle system **102**) may be more of a concern than the benefits of controlling the vehicle to improve fuel consumption, to reduce emissions, or to reduce travel time.

The preceding examples of possible second objectives are exemplary only and are not intended to be limiting. Optionally, the second objective may include more than one of the objectives listed above. For example, the operational settings may be designated to stop the vehicle system **102** within a designated threshold distance of a designated stopping location while controlling multiple vehicles of the vehicle system **102** to be bunched together once the vehicle system **102** is stopped.

In an embodiment, the controller **136** monitors the progress of the vehicle system **102** along the route **104** during a trip. For example, the controller **136** may compare the actual movements of the vehicle system **102** to the projected movements of the vehicle system **102** in a trip plan to determine whether to modify or update the trip plan. In addition, the controller **136** may monitor the operating condition of the vehicle system **102** relative to the designated threshold to determine when to switch between the first operating mode and the second operating mode (e.g., to determine whether the first objective or the second objective is appropriate). The controller **136** may receive speed parameters associated with a current speed of the vehicle system **102** from the speed sensor **116**. The controller **136** may compare the current speed of the vehicle system **102** to the threshold speed to determine whether to operate in the first or second operating mode. The controller **136** also may receive location parameters from the locator device **124** to determine a proximity of the vehicle system **102** to designated locations (such as stopping locations).

Referring to the speed profile **200**, the vehicle system **102** starts moving on the trip from the departure location at time T_1. From time T_1 to time T_2, the speed of the vehicle system **102** increases, but the speed is below the threshold speed V_{TH}. Thus, the controller **136** operates in the second operating mode, and the controller **136** designates operational settings (e.g., according to a trip plan) to drive the vehicle system **102** toward achievement of the second objective. For example, as the vehicle system **102** accelerates from time T_1 to T_2, the second objective may be to reduce wheel slip. The speed of the vehicle system **102** surpasses the threshold speed V_{TH} at time T_2 and travels faster than the threshold speed V_{TH} until time T_3. The speed sensor **116** is used to determine when the vehicle system **102** crosses the threshold speed V_{TH}. The controller **136** therefore operates in the first operating mode between times T_2 and T_3, such that the designated operational settings may drive the vehicle system **102** toward achievement of the first objective (e.g., reducing fuel consumption, emissions generation, and/or total travel time). Although the route **104** has a designated speed limit V_L, the vehicle system **102** may travel slower than the speed limit in order to improve fuel efficiency or reduce emissions as compared to the vehicle system **102** traveling at the speed limit V_L.

The vehicle system **102** may slow to a stop at a designated stopping location roughly midway along the duration of the trip. As the vehicle system **102** slows, the speed of the vehicle system **102** falls below the threshold speed V_{TH} at time T_3. Thus, as the vehicle system **102** slows to a stop after time T_3, the controller **136** may designate operational settings that drive the vehicle system **102** to achieve the second objective. The second objective may be to stop the vehicle system **102** within a threshold distance from a designated location, to stop the vehicle system **102** such that the vehicles are bunched, to slow the vehicle system **102** to reduce wheel slip, or the like. Once the vehicle system **102** starts moving along the trip again, the speed does not surpass the threshold speed V_{TH} until T_4. Optionally, from T_4 to T_5, the vehicle system **102** may be subject to a slow order (e.g., a temporary reduced speed limit), which explains the reduced speed. The vehicle system **102** may subsequently slow again due to a different slow order. The second slow order may force the vehicle system **102** to travel slower than the threshold speed V_{TH} between times T_6 and T_7. Thus, the controller **136** may designate operational settings that control the vehicle system **102** to achieve the second objective from time T_6 to T_7 even though the vehicle system **102** does not come to a stop during this period of time. The vehicle system **102** travels faster than the threshold speed V_{TH} between times T_7 and T_8. The vehicle system **102** arrives at the destination location at time T_9. From time T_8 to time T_9, the controller **136** operates in the second operating mode to control movement of the vehicle system **102** to achieve the second objective.

Optionally, the controller **136** may generate a single trip plan prior to the trip of the vehicle system **102**. The trip plan includes both operational settings toward achievement of the first objective and operational settings toward achievement of the second objective. Thus, when the controller **136** determines that the speed of the vehicle system **102** crosses the designated threshold speed V_{TH}, the controller **136** implements the operational settings of the trip plan that corresponds to the objective associated with the speed. In an alternative embodiment, the controller **136** designates a single trip plan, but the trip plan only includes operational settings that drive the vehicle system **102** toward achievement of the first objective or the second objective, but not both. Thus, as the vehicle system **102** travels at a speed that corresponds to the objective of the trip plan, the controller **136** implements the operational settings of the trip plan. But, when the speed of the vehicle system **102** crosses the threshold speed V_{TH}, the controller **136** may be configured to generate a modification or update to the trip plan, where the modification designates operational settings to drive the vehicle system **102** toward achievement of the other objective. The controller **136** may generate the modified trip plan in real time during the trip. In another embodiment, instead of a single trip plan, the controller **136** may designate two different trip plans for the trip. The first trip plan includes operational settings toward achievement of the first objective, and the second trip plan includes operational settings toward achievement of the second objective. The controller **136** monitors the speed of the vehicle system **102** during the trip relative to the threshold speed V_{TH} to determine whether to implement the operational settings of the first trip plan or the second trip plan.

In an alternative embodiment, the controller **136** does not generate the one or more trip plans for the trip. Instead, the trip plan(s) may be computed previously by the controller **136** for a previous trip of the vehicle system **102** or by a different control system. During the trip of the vehicle system **102**, the controller **136** accesses the one or more trip plans and designates operational settings to drive the vehicle system **102** according to the one or more trip plans. The controller **136** selects which trip plan and/or which operational settings to designate as the vehicle system **102** travels based on the monitored speed of the vehicle system **102** relative to the threshold speed V_{TH}. Thus, even if the controller **136** does not generate the trip plan specific to an upcoming trip, the controller **136** still designates operational settings that have changing objectives based on the operating condition of the vehicle system **102**.

FIG. **3** is a schematic diagram showing a route profile **300** of the vehicle system **102** traveling on a segment of the route **104** during a trip. The segment of the route **104** extends from a starting location **302** to an ending location **304**. The starting location **302** may be a departure location for the trip and/or the ending location **304** may be a destination location for the trip. The route profile **300** illustrates the distance between the starting location **302** and the ending location **304**. The vehicle system **102** on the route **104** travels from the starting location **302** towards the ending location **304** in a forward direction **306**. The trip also designates a break location **308** where the vehicle system **102** is scheduled to stop for a period of time. The designated break location **308** is located just less than halfway across the segment of the route **104** on the illustrated route profile **300**.

In an embodiment, the operating condition that is used to determine the operating mode of the controller **136** is a proximity of the vehicle system **102** to a designated location along the route **104**. The designated threshold is a threshold proximity (shown in FIG. **3** as P_{TH}). The proximity of the vehicle system **102** to a designated location may be used as the operating condition instead of, or in addition to, the speed of the vehicle system **102**. In an embodiment, the controller **136** may operate in a first operating mode when the location of the vehicle system **102** is at least at or outside of the threshold proximity from a designated location along the route **104**. Conversely, the controller **136** operates in the second operating mode when the location of the vehicle system **102** is within the threshold proximity of one of the designated locations. Thus, when the vehicle system **102** is within the threshold proximity, the operational settings are designated to drive the vehicle system **102** toward achievement of the second objective, such as to provide fine motor control for accurate stopping, bunching of the vehicles, and/or reduced wheel slip. On the other hand, when the vehicle system **102** is outside of the threshold proximity, the operational settings are designated to drive the vehicle system **102** toward achievement of the first objective, such as to reduce fuel consumption, emissions generation, and/or total travel time. Although distance or proximity is being used as the operating condition in this embodiment instead of speed, optionally the first and second operating modes of the controller **136** (and the first and second objectives of the trip) may be the same as described above.

The threshold proximity is a distance that is selected prior to the trip. The threshold proximity may be on the order of kilometers or miles. For example, the threshold proximity may be a distance between 0.5 miles and 3 miles, or, more specifically, between 1 to 2 miles. In various embodiments, the threshold proximity could be 1 mile, 1.5 miles, or 2 miles from a designated location. The threshold proximity may be determined based on the specific vehicle system or route. For example, the threshold proximity may be longer if the grade of the route is downhill (which would require more braking force) and/or if the vehicle system has relatively poor braking abilities compared to other vehicle systems that travel on the route **104**. Other considerations may include the size of the vehicle system, including weight, and the speed that the vehicle system travels outside of the threshold proximity, which could affect the inertia of the vehicle system.

In an embodiment, the controller **136** monitors the progress of the vehicle system **102** along the route **104** during the trip. The controller **136** may receive location parameters associated with a current location of the vehicle system **102** communicated from the locator device **124**. The controller **136** may compare the current location of the vehicle system **102** to the location of the nearest designated location to determine the operating mode of the controller **136**. For example, the controller **136** may measure a proximity of the vehicle system **102** to the designated location, and the controller **136** may compare the measured proximity to the threshold proximity to determine if the vehicle system **102** is within the threshold proximity or not at a given time. In another example, the controller **136** knows the location of the designated locations, and the controller **136** determines a threshold boundary line by adding and subtracting the distance of the threshold proximity to each of the designated locations. Then, the controller **136** uses the locator device **124** to determine when the vehicle system **102** crosses one of the threshold boundary lines to know whether the vehicle system **102** is within the threshold proximity.

Referring to the route profile **300** of FIG. **3**, the vehicle system **102** is currently located between the starting location **302** and the break location **308**, and the vehicle system **102** is moving towards the break location **308**. In FIG. **3**, threshold boundary lines **310** are traced in dashed lines around the designated locations **302**, **308**, **304**. The threshold boundary lines **310** are circular curves that have a radius of the threshold proximity PTE. Thus, when the vehicle system **102** is within any of the boundary lines **310**, the vehicle system **102** is less than the threshold proximity from a designated location, so the controller **136** operates in the second operating mode. In FIG. **3**, the vehicle system **102** is not currently within any threshold boundary line **310**, so the controller **136** operates in the first operating mode. The controller **136** designates operational settings that drive the vehicle system **102** toward achievement of the first objective in the first operating mode. Thus, at the illustrated position, the operational settings may be driving the vehicle system **102** in order to increase fuel efficiency, reduce emissions, or reduce total travel time.

When the vehicle system **102** crosses a point **312** to enter the threshold boundary line **310** surrounding the break location **308**, the controller **136** switches to the second operating mode. In the second operating mode, the controller **136** designates operational settings that drive the vehicle system **102** toward achievement of the second objective, such as to accurately stop the vehicle system **102** at the break location **308**, to provide bunching between the vehicles of the vehicle system, and/or to reduce wheel slip when slowing to a stop at the break location **308**. The controller **136** remains in the second operating mode through the initial acceleration of the vehicle system **102** from the break location **308** until the vehicle system **102** crosses another point **314** at the back end of the threshold boundary line **310** surrounding the break location **308**. Then, the controller **136** operates in the first operating mode (designating operational settings to drive the vehicle system **102** toward achievement of the first objective) until the vehicle system **102** crosses a point **316** to enter the threshold boundary line **310** surrounding the ending location **304** of the segment of the route **104**. From the point **316** to the ending location **304**, the controller **136** operates in the second operating mode. Thus, as with the embodiment shown in FIG. **2**, when the vehicle system **102** is approaching a stop location or accelerating from a stop location, the controller **136** operates in the second operating mode to provide fine motor control of the vehicle system **102**. But, when the vehicle system **102** is not near a stop location, the controller **136** operates in the first operating mode to provide fuel efficiency, reduced emissions, and/or reduced travel time.

In the embodiments shown in FIGS. **2** and **3**, the controller **136** is described as having two operating modes depending on whether the operating condition is over a threshold or below the threshold. Optionally, the controller **136** may have more than two operating modes in order to designate operational settings that have at least three different objectives depending on the operating condition of the vehicle system **102**. For example, the controller **136** may compare actual operating conditions of the vehicle system **102** to two designated thresholds. The operating mode of the controller **136** could be determined based on whether the operating condition is below both thresholds, is between the two thresholds, or is above both thresholds. Thus, the control system **100** may be configured to differentiate and control the vehicle system **102** toward the achievement of more than two different objectives.

FIG. **4** is a flow chart of one embodiment of a method **400** for controlling a vehicle system that travels on a track along a route. At **402**, a trip plan for a trip of the vehicle system along the route is generated. The trip plan may be generated by a controller that includes one or more processors. The trip plan designates one or more operational settings for the vehicle system as a function of one or more of time or distance along the route. The operational settings are designated to drive the vehicle system toward achievement of one or more objectives of the trip plan. Generating the trip plan may include designating one or more of speeds, throttle settings, brake settings, or accelerations as the operational settings of the trip plan. The trip plan may be generated to drive the vehicle system toward achievement of the one or more objectives while satisfying one or more of speed limits, vehicle capability constraints, trip schedule times, or emissions limits.

At **404**, an operating condition of the vehicle system is monitored as the vehicle system travels along the route during the trip. In one embodiment, the operating condition may be a speed of the vehicle system. In another embodiment, the operating condition may be a proximity of the vehicle system to a designated location along the route, such as a designated stop location where the vehicle system is to slow to a stop. At **406**, a determination is made whether the monitored operating condition is at least at or greater than a designated threshold. The designated threshold may be a threshold speed, such as a speed between 5 mph and 15 mph. The determination may be made by comparing a current speed of the vehicle system as monitored by a speed sensor to the designated threshold speed. Alternatively, the designated threshold may be a threshold proximity to a designated location for the trip, such as a stop location. The threshold proximity may be a distance of 1 mile or 2 miles from a stop location. The determination may be made by comparing a current location of the vehicle system as monitored by a locator device to the location of the nearest stop location and measuring whether that distance is more or less than the designated threshold proximity.

If the operating condition is at or greater than the designated threshold (e.g., such as the speed of the vehicle system being faster than the threshold speed or the distance of the vehicle system to a stop location being further than the threshold proximity), flow of the method **400** proceeds to **408**. At **408**, operational settings according to the trip plan are designated to drive the vehicle system toward achievement of a first objective. The first objective may include one or more of a reduction in fuel consumption or a reduction in emissions generation by the vehicle system relative to the vehicle system traveling along the route for the trip according to operational settings that differ from the one or more operational settings of the trip plan.

If, on the other hand, the operating condition at **406** is less than the designated threshold (e.g., such as the speed of the vehicle system being slower than the threshold speed or the distance of the vehicle system to a stop location being less than the threshold proximity), flow of the method **400** proceeds to **410**. At **410**, operational settings according to the trip plan are designated to drive the vehicle system toward achievement of a second objective that differs from the first objective. The second objective may be associated with fine control of the movements of the vehicle system. For example, the second objective may include moving the vehicle system to one or more locations that are within a designated threshold distance of one or more designated locations of the trip plan. More specifically, the second objective may include stopping the vehicle system at one or more locations that are within a designated threshold distance of one or more designated stopping locations of the trip plan. The second objective alternatively or additionally may include stopping the vehicle system such that multiple vehicles of the vehicle system are bunched together with one or more couplers disposed between the vehicles of the vehicle system in a slack state once the vehicle system is stopped according to the trip plan. Furthermore, the second objective may include moving the vehicle system on the route such that one or more wheels of the vehicle system retain adhesion with the route to reduce wheel slip.

Optionally, the method **400** may further include communicating a control signal to at least one of a propulsion subsystem, a braking subsystem, or a user interface device of the vehicle system. The control signal may include at least some of the operational settings of the trip plan. The operational settings in the control signal may be implemented by the recipient of the control signal, such as autonomously or via human intervention.

At least one technical effect of the various embodiments described herein is determining and implementing a driving and/or operating strategy of a powered vehicle system to improve at least certain objective operating criteria while satisfying schedule, speed, and other constraints. Another technical effect is the ability for the vehicle system to achieve different objectives during the route based on which objectives are relevant at different operating conditions of the vehicle system along the route. A further technical effect is increased control of the vehicle system throughout the trip, including at or near stopping locations, such that the vehicle system can stop within a designated threshold distance of a designated stopping location. The increased control may allow multiple vehicles of the vehicle system to have a designated amount of slack between the vehicles when the vehicle system is stopped. The increased control may also allow for a decreased likelihood of wear of the vehicle system and/or the route near stopping locations attributable to wheel slip.

In one embodiment, a method (e.g., for controlling a vehicle system along a route) includes generating a trip plan for a trip of the vehicle system along the route. The trip plan designates one or more operational settings for the vehicle system as a function of one or more of time or distance along the route. The one or more operational settings are designated to drive the vehicle system toward achievement of one or more objectives of the trip plan. The trip plan is generated to drive the vehicle system during the trip toward achievement of a first objective during movement of the vehicle system along the route at a speed that is at least as fast as a designated threshold speed. The trip plan is generated to drive the vehicle system during the trip toward achievement of a different, second objective during movement of the vehicle system along the route at a speed that is slower than the designated threshold speed.

In an aspect, generating the trip plan includes designating one or more of speeds, throttle settings, brake settings, or accelerations as the operational settings of the trip plan.

In another aspect, the first objective includes one or more of a reduction in fuel consumption by the vehicle system, a reduction in emissions generation by the vehicle system, an improvement in handling of the vehicle system, or a reduction in travel time relative to the vehicle system traveling along the route for the trip according to operational settings that differ from the one or more operational settings of the trip plan.

In another aspect, the second objective includes moving the vehicle system to one or more locations that are within a designated threshold distance of one or more designated locations of the trip plan.

In another aspect, the second objective includes stopping the vehicle system at one or more locations that are within a designated threshold distance of one or more designated stopping locations of the trip plan.

In another aspect, the second objective includes stopping the vehicle system such that multiple vehicles of the vehicle system are bunched together with one or more couplers disposed between the vehicles of the vehicle system in a slack state once the vehicle system is stopped according to the trip plan.

In another aspect, the second objective includes moving the vehicle system on the route such that one or more wheels of the vehicle system retain adhesion with the route to reduce wheel slip.

In another aspect, the designated threshold speed is a speed between 5 miles per hour and 15 miles per hour.

In another aspect, the method further includes monitoring the speed of the vehicle system as the vehicle system travels along the route during the trip and comparing the speed to the designated threshold speed.

In another aspect, the method further includes communicating a control signal to at least one of a propulsion subsystem, a braking subsystem, or a user interface device of the vehicle system. The control signal includes at least some of the operational settings of the trip plan.

In another aspect, the trip plan is generated to drive the vehicle system during the trip toward achievement of at least one of the first objective or the second objective while satisfying one or more of speed limits, vehicle capability constraints, trip schedule times, or emissions limits.

In another embodiment, a system (e.g., a control system for controlling a vehicle system along a route) includes a sensor and a controller that includes one or more processors. The sensor is configured to monitor an operating condition of the vehicle system during movement of the vehicle system along the route for a trip. The controller is configured to designate one or more operational settings for the vehicle system as a function of one or more of time or distance along the route. The one or more operational settings are designated to drive the vehicle system toward achievement of one or more objectives for the trip. The controller is operable in at least two operating modes including a first operating mode and a second operating mode. The controller operates in the first operating mode when the operating condition of the vehicle system is at least one of at or above a designated threshold. The controller in the first operating mode is configured to designate operational settings to drive the vehicle system during the trip toward achievement of a first objective during movement of the vehicle system along the route. The first objective includes one or more of a reduction in fuel consumption or a reduction in emissions generation by the vehicle system relative to the vehicle system traveling along the route for the trip according to operational settings that differ from the one or more operational settings designated by the controller. The controller operates in the second operating mode when the operating condition of the vehicle system is below the designated threshold. The controller in the second operating mode is configured to designate operational settings to drive the vehicle system during the trip toward achievement of a different, second objective during movement of the vehicle system along the route.

In an aspect, the operating condition of the vehicle system is a speed of the vehicle system along the route, and the designated threshold is a threshold speed. The sensor may be a speed sensor that is configured to determine the speed of the vehicle system along the route. The speed sensor may be configured to communicate the speed of the vehicle system to the controller. The controller may be configured to compare the speed of the vehicle system to the threshold speed.

In another aspect, the operating condition of the vehicle system is a proximity of the vehicle system to a designated location along the route for the trip, and the designated threshold is a threshold proximity. The sensor may be a locator device configured to determine a location of the vehicle system along the route. The locator device may be configured to communicate the location of the vehicle system to the controller. The controller may be configured to determine the proximity of the vehicle system to the designated location and compare the proximity to the threshold proximity.

In another aspect, the controller is configured to designate one or more of speeds, throttle settings, brake settings, or accelerations for the vehicle system as the operational settings.

In another aspect, the second objective includes moving the vehicle system to one or more locations that are within a designated threshold distance of one or more designated locations of the trip.

In another aspect, the second objective includes stopping the vehicle system such that multiple vehicles of the vehicle system are bunched together with one or more couplers disposed between the vehicles of the vehicle system in a slack state once the vehicle system is stopped.

In another aspect, the second objective includes moving the vehicle system on the route such that one or more wheels of the vehicle system retain adhesion with the route to reduce wheel slip.

In another aspect, the controller is further configured to communicate a control signal to at least one of a propulsion subsystem, a braking subsystem, or a user interface device of the vehicle system. The control signal includes at least some of the operational settings designated by the controller.

It is to be understood that the above description is intended to be illustrative, and not restrictive. For example, the above-described embodiments (and/or aspects thereof) may be used in combination with each other. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the subject matter described herein without departing from its scope. While the dimensions and types of materials described herein are intended to define the parameters of the disclosed subject matter, they are by no means limiting and are exemplary embodiments. Many other embodiments will be apparent to one of ordinary skill in the art upon reviewing the above description. The scope of the inventive subject matter should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. In the appended claims, the terms “including” and “in which” are used as the plain-English equivalents of the respective terms “comprising” and “wherein.” Moreover, in the following claims, the terms “first,” “second,” and “third,” etc. are used merely as labels, and are not intended to impose numerical requirements on their objects. Further, the limitations of the following claims are not written in means-plus-function format and are not intended to be interpreted based on 35 U.S.C. § 112(f), unless and until such claim limitations expressly use the phrase "means for" followed by a statement of function void of further structure.

This written description uses examples to disclose several embodiments of the inventive subject matter, including the best mode, and also to enable a person of ordinary skill in the art to practice the embodiments of inventive subject matter, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the inventive subject matter is defined by the claims, and may include other examples that occur to a person of ordinary skill in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

Since certain changes may be made in the above-described systems and methods, without departing from the spirit and scope of the inventive subject matter herein involved, it is intended that all of the subject matter of the above description or shown in the accompanying drawings shall be interpreted merely as examples illustrating the inventive concept herein and shall not be construed as limiting the inventive subject matter.

What is claimed is:

1. A system comprising:
a sensor configured to monitor an operating condition of a vehicle system while moving; and
one or more processors configured to receive data output from the sensor and to generate a trip plan based on the data that is output from the sensor, the trip plan designating operational settings for control of the vehicle system;
wherein the operational settings of the trip plan include different operational modes with the vehicle controlled according to the different operational modes based on changes in the operating condition relative to one or more thresholds, the operational modes including at least one of:
the one or more processors configured to control the vehicle system such that vehicles in the vehicle system are bunched together with a coupler between the vehicles being in a slack state; or
the one or more processors configured to stop the vehicle system such that one or more wheels of the vehicle system retain adhesion with the route.

2. The system of claim **1**, wherein at least one of the operational modes includes controlling the vehicle system such that vehicles in the vehicle system are bunched together with the coupler between the vehicles being in the slack state.

3. The system of claim **1**, wherein the operating condition of the vehicle system is a speed of the vehicle system.

4. The system of claim **1**, wherein the operating condition of the vehicle system is a distance of the vehicle system from a location along the one or more routes.

5. The system of claim **1**, wherein the operational settings are one or more of a speed, a throttle setting, a brake setting, or an acceleration.

6. The system of claim **1**, wherein at least one of the operational modes includes the one or more processors controlling a speed of vehicle system to be above a threshold speed.

7. The system of claim **1**, wherein at least one of the operational modes includes the one or more processors stopping the vehicle system within a designated threshold distance of a stopping location.

8. The system of claim **1**, wherein at least one of the operational modes includes the one or more processors stopping the vehicle system such that each vehicle in the vehicle system stops after a preceding vehicle in the vehicle system.

9. The system of claim **1**, wherein at least one of the operational modes includes the one or more processors stopping the vehicle system such that the one or more wheels of the vehicle system retain adhesion with the route.

10. The system of claim **1**, wherein at least one of the operational modes includes the one or more processors controlling a distance between vehicles of the vehicle system.

11. The system of claim **1**, wherein at least one of the operational modes includes the one or more processors controlling a tension between vehicles of the vehicle system.

12. A method comprising:
monitoring an operating condition of a vehicle system while moving using a sensor;
generating a trip plan based on data that is output from the sensor, the trip plan designating operational settings for control of the vehicle system,
wherein the operational settings of the trip plan include different operational modes with the vehicle controlled according to the different operational modes based on changes in the operating condition relative to one or more thresholds; and
one or more of:
controlling the vehicle system according to a first mode of the operational modes such that vehicles in the vehicle system are bunched together with a coupler between the vehicles being in a slack state; or
stopping the vehicle system according to a second mode of the operational modes such that one or more wheels of the vehicle system retain adhesion with the route.

13. The method of claim **12**,
wherein the method includes controlling the vehicle system according to the first mode of the operational modes such that the vehicles in the vehicle system are bunched together with the coupler between the vehicles being in the slack state.

14. The method of claim **12**, wherein the operating condition of the vehicle system is a speed of the vehicle system.

15. The method of claim **12**, wherein the operating condition of the vehicle system is a distance of the vehicle system from a location along the one or more routes.

16. The method of claim **12**, wherein the operational settings are one or more of a speed, a throttle setting, a brake setting, or an acceleration.

17. The method of claim **12**, further comprising:
controlling a speed of vehicle system to be above a threshold speed while operating in at least one of the operational modes.

18. A method comprising:
monitoring, with at least one sensor, an operating condition of a vehicle system;
determining whether the operating condition differs from one or more thresholds each associated with a different operating mode of the vehicle system;
generating a trip plan for the vehicle system that designates operational settings for the vehicle system, the

trip plan generated based on which of the one or more thresholds from which the operating condition differs, each of the one or more thresholds associated with a different operational mode of the vehicle system; and

controlling movement of the vehicle system according to the operational settings designated by the trip plan, the movement of the vehicle system controlled by stopping the movement of the vehicle system such that each vehicle in the vehicle system stops after another, preceding vehicle in the vehicle system.

19. The method of claim **18**, wherein generating the trip plan includes designating one or more of speeds, throttle settings, brake settings, or accelerations as the operational settings of the trip plan.

20. The method of claim **18**, wherein at least one of the operational modes includes one or more of:

reducing emissions generated by the vehicle system,

changing handling of the vehicle system, or

reducing travel time of the vehicle system.

21. The method of claim **18**, wherein the vehicle system is formed of the vehicles coupled with each other.

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